INDUSTRIAL SAND AND GRAVEL

By Wallace P. Bolen

Mr. Bolen, a physical scientist, has been the commodity specialist for industrial sand and gravel since October 1988. Domestic survey data were prepared by Christopher H. Lindsay, statistical assistant; and the international production table was prepared by Ronald Hatch, international data assistant.

Probably no other nonmetallic mineral has more diversified uses than silica (industrial) sand, mainly because of its common occurrence around the world and its distinctive physical characteristics, including hardness, resistance to high temperature and chemical action, and relatively low price. Silica sand is the major component of common glasses, foundry molding and cores, abrasive blast sand, and hydraulic fracturing sand. Industrial sand and gravel is also important in ceramics, chemicals, and fillers for rubber and plastics, and also is utilized in golf courses, as a flux in smelting and chemical production, as filter media, and in many other uses.

DOMESTIC DATA COVERAGE

Production of industrial sand and gravel in 1991 decreased to 25.6 million short tons, about 10% less than 1990's production. Production decreased for the second year in a row, to its lowest level since 25.3 million tons was produced in 1967. During 1991, the following silica markets saw decreases in consumption: glass containers, fiberglass, foundry sand, blast sand, chemicals, and hydraulic fracturing sand (frac sand).

Exports of silica sand and gravel increased about 42% in quantity, but the average value per ton, compared with that of 1990, decreased 10%. Imports of industrial sand and gravel increased about 25% in quantity, but the associated value decreased 70%. Domestic apparent consumption of industrial sand and gravel in 1991 was 24.1 million short tons, a decrease of almost 12% compared with that of 1990.

Domestic production data for industrial sand and gravel were developed by the U.S. Bureau of Mines from voluntary surveys of U.S. producers. Of the 152 industrial sand and gravel operations surveyed, 119 (78%) reported to the U.S. Bureau of Mines. Their combined production represented about 86% of the U.S. total published in table 1. The production of nonrespondents was estimated mostly using employment data. Of the 152 operations, 148 (97%) were active and 4 idle. *(See table 1.)*

BACKGROUND

One of the first industries to use silica sand was the glass industry. At least 4,000 years ago, long before iron was smelted, glassmaking was already a known craft. Although the place and date of the first manufactured glass are not known, the oldest known specimens of glass are from Babylon (ca. 2600 B.C.) and from Egypt (ca. 2500 B.C.), where the industry was well established by about 1500 B.C. Many varieties of glass were known during Roman times. Little is known of the glassmaking methods used in Europe from the fall of Rome until the 10th century, when stained glass was produced in Venice. After this, Venice remained the leader in fine glassware for the next four or five centuries. In the 17th century, a process for casting glass was invented in France, and later, England began to make flint glass, marking the beginning of modern glass technology.

Glassmaking was apparently the first industry to be transplanted from Europe to North America, first to Mexico and later to the British colonies. The first manufacturing establishment in what is now the United States was a glass factory at Jamestown, VA, built in 1608. The 1885 edition of "Mineral Resources of the United States," the predecessor of today's U.S. Bureau of Mines "Minerals Yearbook," reported a total of 317,000 tons of silica sand produced in 1884 in the United States, under "Glass Materials." In 1991, a total of 25.6 million tons of silica sand was produced in the United States for a variety of uses, of which 11.2 million tons was for glassmaking. Today, glass has become an invaluable product with a multitude of forms and applications.

Metals casting was probably the second industry that used silica sand. Today, the casting industry provides vital components for most modern manufacturing industries. The number of industries using silica sand is growing constantly, as are the products made by using silica sand.

Definitions, Grades, and Specifications

Sand is defined throughout the industry and by the American Society for Testing and Materials (ASTM) as granular rock particles that pass through a No. 4 mesh (0.187-inch) U.S. standard sieve, are retained on a No. 200 mesh (0.0029-inch) sieve, and are the result of natural disintegration or comminution of cemented rock. Industrial sand or silica sand is the term used by the industry for sands that have a very high percentage of silicon dioxide (SiO_2) and are essential materials in glass manufacture, in ferrous and nonferrous foundry operations, in

certain chemical and metallurgical processes, for hydraulic fracturing of oil and gas deposits, and in many manufactured products as fillers or extenders.

Most industrial sands have been named for their specific uses; for example, glass, foundry, abrasive, filler, and hydraulic fracturing sands. Almost invariably, these sands, in addition to being high in silica, consist mostly of quartz grains.

Products for Trade and Industry

Silica sand had a wide range of uses in a significant number of industries, the most important being glass and foundry. Other uses were metallurgical and as abrasives, as fillers, for filtration, and for hydraulic fracturing of rock formations to improve recovery in oil wells.

Glass sand was used as a main constituent for manufacturing glass containers, flat glass, safety glass, pressed and blown glass, fiberglass, and a wide variety of specialty glasses such as optical glass and industrial glass.

Glass sand had to meet rigid specifications with respect to purity and silica content, depending on the kind of glass being manufactured. Only a very small amount of iron oxide and chromium compounds could be tolerated, and a high percentage of aluminum, calcium, or magnesium oxides was undesirable. The standards of the American Ceramic Society for glass sand indicated that all grains should pass through a No. 20 mesh screen, between 40% and 60% should be retained on a No. 60 screen, between 10% and 20% on a No. 80 screen, and not more than 5% should pass a No. 100 screen. Sand for first-quality optical glass should contain 99.8% SiO_2 and a maximum of 0.1% aluminum oxide (Al_2O_3) and 0.02% iron oxide (Fe_2O_3). Third-quality flint glass could contain only 95% SiO_2 and as high as 4% Al_2O_3. Only in the low-quality amber glass was the content of Fe_2O_3 permitted to reach 1%.

Most glass manufacturers established their own specifications for the physical size and chemical purity of the raw materials that have to be met by the suppliers of glass sand. Recently, glass manufacturers showed an increased interest in finer glass sands because processing of smaller particles required lower temperatures and, therefore, reduced the consumption of energy.

Foundry sands included molding sand and core sand that were used for casting iron-, aluminum-, and copper-base alloys. Required properties included cohesiveness sufficient to hold together the mold or core when moist, which is achieved by a bonding agent; refractoriness to withstand the high temperature of the molten metal; strength to resist the weight of the metal; permeability to release vapors and gases generated during cooling of the metal; and proper texture and composition to produce a smooth casting that will not react with the metal. Most metals were cast in "green sand," which is a mixture of silica and clay, although to a lesser extent, resins or oils were also used as a bonding agent instead of clays. In the case of naturally bonded foundry sands, the amount of clay minerals present affected their usefulness. Standard tests and specifications for foundry sands were published by the American Foundrymen's Society.[1]

Refractory sands were used in the manufacture of silica brick and tile, quartzite (gannister) being the commonly used raw material. Required properties were "the capability of maintaining the desired degree of chemical and physical identity at high temperatures" and resistance to abrasion, impact, thermal shock, and high level of load. Refractory silica materials were classified based on their general composition and on their distinctive properties. Standard classifications and specifications for silica refractory brick were published by the ASTM.[2]

Quartz sands, on the Knoop scale at 820, are quite hard and are one of the oldest abrasives known. Abrasive sands were quartz sands used in stone sawing, glass grinding, metal polishing, and sand blasting. No rigid specifications existed for these sands, but sound, clean, hard, and closely sized sand grains were required. Purity and grain-shape specifications varied with the type of abrasive action and the requirements of the final product. An angular particle shape with sharp cutting edges was generally required.

Hydraulic fracturing sand was pumped into oil or natural gas wells as a sand-liquid mixture to break up petroleum-bearing formations and act as a propping agent, allowing oil or gas to move more freely toward the producing wells. Some of the major requirements for fracturing sands were spherical, well-rounded grains of clean, dried, and well-screened quartz sand, free of any materials such as feldspar, calcite, and clay. The most common size was 20/40 mesh; other sizes included 6/12, 8/16, 12/20, 40/70, and 70/140, but these sands represented only about 15% of the total sand used as proppant. "Recommended Practices for Testing Sand Used in Hydraulic Fracturing Operations," published by the American Petroleum Institute, was used as a guide by industry.[3]

Ground sand or silica flour has found wide industrial application as a filler in paint, plastics, rubber, ceramics, and a variety of other products. Mainly because of the diversity of its uses, no standard specifications exist for the silica flour used in most of these applications except grain size and chemical composition.

Silicon carbide, which was used as an abrasive, for refractory uses, and in specialty ceramics, was produced by the reaction of silica sand (60%) and coke (40%) at elevated temperatures up to 2,400° C.

Metallurgical sand was used as a fluxing agent for basic oxides in various smelting operations and as a source of silicon in ferrosilicon manufacture. The ferrosilicon was a steel alloying additive. Filter sand was used extensively in filtering water for municipal and industrial use and swimming pools and in sewage treatment plants. Engine sand was used in locomotive haulage to improve traction. Other sands were used in special cements, in manufacturing silica brick and tiles for furnace linings and beds, for coal washing, and in manufacturing pottery. Industrial sand

fulfill chemical and metallurgical requirements, for example the hydraulic fracturing of oil and gas deposits, and in many nonstructural products such as filters or abrasives.

Most industrial sands have been named for their specific uses, for example, glass, foundry, refractory, filter, and hydraulic fracturing sands. Abrasive materials, these sands, in addition to other high in silica, require purity of quartz grains.

Products for Trade and Industry.

Silica sand had a wide range of uses in a significant number of industries, the most important being glass and foundry. Other uses were metallurgical and as abrasives, as filters, for filtration, and for hydraulic fracturing of rock formations to improve recovery in oil wells.

Glass sand was used as a main constituent for manufacturing glass containers, flat glass, utility glass, pressed and blown glass, fiberglass, and a wide variety of specialty glasses such as optical glass and laboratory glass.

Glass sand had to meet rigid specifications with respect to purity and silica content, depending on the kind of glass being manufactured. Only a very small amount of iron oxide and chromium components could be tolerated, and a high percentage of aluminum, calcium, or magnesium oxides was undesirable. The standards of the American Ceramic Society for glass sand indicated that all grains should pass through a No. 20 mesh screen, between 40% and 60% should be retained on a No. 40 screen, between 10% and 20% on a No. 50 screen, and not more than 5% should pass a No. 100 screen. Sand for first-quality optical glass should contain 99.8% SiO_2, and a maximum of 0.1% aluminum oxide (Al_2O_3) and 0.02% iron oxide (Fe_2O_3). Third-quality flint glass sands contain only 98.5% SiO_2 and as high as 0.5% Al_2O_3. Only in the ninth quality amber glass was the content of Fe_2O_3 permitted to reach 1%.

Many glass manufacturers established their own specifications for the physical and chemical purity of the raw products that were to be sold to the suppliers of glass sand. Generally, glass manufacturers wanted an increased alumina in their glass sands because the presence of alumina permitted somewhat lower temperatures and, therefore, reduced the consumption of energy.

Foundry sand includes molding sand and core sand that served as the principal raw materials and an essential part of foundry operations. Molding sand, or bond together the sand in place when mixed, which is combined with a bonding agent, refers to the ability to withstand the high temperatures of the molten metal, strength to resist the weight of the metal, permeability to release vapors and gases generated during cooling of the metal, and proper texture and composition to produce a smooth casting that will not react with the metal. Most metals were cast in "green sand," which is a mixture of silica and clay, although to a lesser extent, resins or oils were also used as a bonding agent instead of clays. In the case of naturally bonded foundry sands the amount of clay minerals was of greater than usefulness. Sands for testing and specifications for foundry sands were published by the American Foundrymen's Society.

Refractory sands were used for the manufacture of silica brick and "tile" materials (ganister) having a high content of silica. Refractory materials required properties to withstand a high degree of chemical and physical effects at high temperatures, resistance to abrasion, impact, thermal shock, and high level of heat. Refractory silica materials were classified based on their general composition and on their distinctive properties. Standard classifications and specifications for silica refractory brick were published by the ASTM.

Abrasive sands, on the Mohs scale of hardness, are quite hard and are one of the oldest abrasives known. Abrasive sands were commonly used in stone sawing, glass grinding, metal polishing, and sandblasting. For sandblasting, sharp angular grains of one size, free from dust, iron oxide, and closely sized sand grains were required. Purity was generally specifications varied with the type of blasting surface and the requirements of the final product. An angular particle shape with sharp cutting edges was generally required.

Hydraulic fracturing sand was pumped into oil or natural gas wells in a rock liquid mixture to break up petroleum-bearing formations and act as a propping agent, allowing oil or gas to move more freely toward the producing wells. Some of the major requirements for fracturing sands were spherical, well rounded grains of sand, often the well-screened quartz sand, free of any materials such as feldspar, calcite, and clay. The most common sizes for hydraulic sands, often were indicated 8/16, 20/40, 12/20, 40/70, and 70/140, but those sizes represented only about 15% of the total sand used as proppants. "Recommended Practices for Testing Sand Used in Hydraulic Fracturing Operations," published by the American Petroleum Institute, was used as a guide in this regard.

Ground sand or silica flour has found wide industrial application as a filler in paint, plastics, rubber, ceramics, and a variety of other products. Mostly because of the diversity of its uses, no standard specifications exist for the silica flour used in most of these applications except grain size and chemical composition.

Silicon carbide, which was used as an abrasive, for refractory uses, and in specialty ceramics, was produced by the reaction of silica sand (silica) and coke (C) in an electric furnace at temperatures up to 2,200° C.

Metallurgical sand was used as a fluxing agent for basic metals in various smelting operations and as a source of silicon in ferroalloy manufacturing. The introduction of silica, allowing the silica [illegible] sand was used historically in filtering water for municipal and industrial uses, in treating sewage and waste treatment plants. Traction sand was used on locomotive tracks for improved traction. Other sands were used in special cements, in manufacturing silica brick and tile, for fireproof blocks and roofs, for road marking, and in manufacturing pottery. Industrial sand

was also used for chemical production, golf courses (both in traps and in green construction), and building products. Industrial gravel was used as the source material in the production of silicon and ferrosilicon and as a flux for the production of copper, nickel, and elemental phosphorus. Some gravel was also used as filtration media, mainly in municipal water treatment facilities.

Industry Structure

In 1991, 77 U.S. companies with 148 active operations produced silica sand and gravel. The individual industrial sand and gravel operations ranged in size from those producing about 1 million tons annually to those reporting less than 10,000 tons per year. Most of the production came from large operations that were mostly owned or operated by a small number of companies. In the past 10 to 15 years, there was a gradual trend toward larger operations, mostly because small plants were becoming less economical. The viability of small operations was dependent on demand in local markets, mining conditions, and the degree of processing required to supply the final product.

During the past 10 years, changes within the structure of the industrial sand industry occurred, primarily caused by mergers and acquisitions, some resulting from an influx of foreign capital, mostly from Europe.

Geology-Resources

U.S. resources of industrial sand and gravel were expected to be sufficient to meet domestic demand in the foreseeable future, although their geographic distribution and quality often did not match market requirements. The availability of these reserves was controlled to a significant degree by land use and/or environmental constraints. Reserves of industrial sand and gravel owned or controlled by domestic producers were estimated to total about 3 to 4 billion tons.

Although silica reserve data for the rest of the world were not available, it could be assumed, on the basis of geologic evidence, that world reserves were sufficient to meet demand, even if not always at the locations where needed.

Industrial sand or silica sand was produced in the United States from a variety of geological formations ranging in age from late Precambrian to mid-Tertiary. About 70 stratigraphic units were known as having an economic potential for this industry. Lithologically, these deposits ranged from quartzites, sandstones with different degrees of cementation, quartz conglomerates, chert deposits, and quartz pegmatites to terrace sands and gravels, and dune sands. Most of the high-quality industrial sand was produced from a few geological formations in the Eastern United States. Oriskany sandstone, or more precisely the Ridgeley formation of Early Devonian age, was one important source of silica sand. It extended from New York State to southern Virginia and eastern Ohio, but was being mined only in central Pennsylvania, northwestern Maryland, and northern West Virginia, where the formation was thick enough to be of commercial value. It was a hard, white orthoquartzite with medium to fine, angular and subangular, and well-sorted grains. The St. Peter sandstone of Middle Ordovician age, extending from Wisconsin and Minnesota through Iowa, Illinois, and east-central Missouri, was another major source of industrial sand. The best known center of production of silica sand from this formation was the Ottawa district of La Salle County, IL, where it was known as "Ottawa sand," and to a lesser degree in southern Wisconsin and east-central Missouri. It was a soft and poorly cemented high-purity orthoquartzite with coarse, rounded grains. The weak cement holding the silica grains together was mostly a light-colored clay.

In addition to the two formations just mentioned, the most important sources of industrial sand in the United States, numerous other deposits were also being mined for silica sand in different parts of the country. Included are the Jordan sandstone of Upper Cambrian age in Minnesota and Wisconsin, a primary source of hydraulic fracturing sand; the Raritan formation of Upper Cretaceous age in central New Jersey and the Cohansey sand of probable Miocene age in southern New Jersey; and the Tuscarora quartzite of Lower Silurian age in Pennsylvania and Virginia used for the manufacture of refractory bricks. Other deposits are the Sylvania sandstone of Devonian age in the Detroit area; the Oil Creek and McLish formations of Lower Ordovician age in Oklahoma, a southwestward extension of the St. Peter sandstone; and the Hickory sandstone of Cambrian age in central Texas that produced mostly hydraulic fracturing sand.

In the West, the most important sources of industrial sand were the Ione formation of Eocene age in northern California, the Silverado (Paleocene) and Tejon (Eocene) formations in southern California, and the Eureka quartzite of Middle Ordovician age in central California.

Approximately two-thirds of the U.S. industrial sand and gravel was produced east of the Mississippi River, especially in the industrialized areas of the East North Central, South Atlantic, and Middle Atlantic regions. Of the top five producing States that accounted for about 45% of 1991 production, three—Illinois, Michigan, and New Jersey—were in the East and the other two—California and Texas—were in the West. The concentration of the industrial sand operations in the eastern part of the United States resulted from the existence of high-quality geologic deposits close to the major consuming industries, glass and foundry. In the south and west, demand from the oil and gas industry in the Louisiana, Oklahoma, and Texas area has sustained the growth of industrial sand operations in Texas. California production remained large owing to demands from local industry, particularly the glass container industry, and the distance of California from the traditional production areas in the Midwest.

Technology

Exploration.—A large number of geologic formations with economic potential as a source of industrial sand have been mapped and described in the literature over many years and were, therefore, well known. Consequently, detailed exploration and development work for new industrial sand operations was expected to occur on some of these formations. The qualities of a silica deposit necessary for a viable operation should include proper particle size, chemical composition, degree of cementation, and deposit uniformity. Also, the nature and amount of waste material and the economic feasibility of its removal and possible use or disposal should be studied. The evaluation of the new deposit should also include an environmental impact study as required by most local or State agencies before authorizing a new mining operation.

If the raw material should prove to meet the requirements and adequate reserves are demonstrated, the development stage of the operation could be started. Economic feasibility and marketing studies should be performed by analyzing all factors important for any such mining operations. Included are the availability of power and water supply, mining and processing costs and requirements, and the condition of nearby roads and highways. Other factors include the proximity of rail haulage; the cost of compliance with local, State, and Federal regulations; and the proximity and density of local population as well as its attitude toward such a project.

Mining.—Most industrial sand was mined from open quarries, but a few underground operations existed, mostly because of an exceptionally thick overburden or environmental limitations. Surface mining methods and equipment varied with the type of the geologic formation, size and configuration of the deposit, production capacity, estimated life of the operation, and location of the deposit with respect to urban centers. The mining methods depended primarily on the degree of cementation of the rock, although most open pit mining operations included site clearing and removal of the overburden; mining of the silica rock or sand; processing of the material, including crushing, screening, and classification; and reclamation of the extraction area. Unconsolidated sands, such as the Cohansey of New Jersey, below the ground water level were dredged. Much of the St. Peter sandstone was first loosened by light blasting and then washed down by hydraulic jets or "monitors" into sumps, from which it was pumped to the processing plants. Harder rock such as the Oriskany sandstone required blasting and primary and secondary crushing before it could be processed.

Processing.—Processing of mined silica sand required specialized operations that varied considerably with the nature of the deposit and the physical and chemical requirements of the desired product. Depending on the degree of cementation, several stages of crushing were necessary to achieve the desired size reduction. Gyratory crushers, jaw crushers, impact mills, or roll crushers were used as primary or secondary crushers, and smooth rolls, media mills, autogenous mills, high-speed hammer mills, or fluid energy jet mills were used for grinding the product down to 50 microns and finer. Dry or wet screening was used to separate particles of sizes down to about 150 microns, and wet or air classifiers processed particles from 250 microns into the submicron range. Vibratory screens and gyratory screens, in addition to mechanical, hydraulic, or air classifiers, were used, depending on the size distribution required.

Research for the silica mining industry related not only to new methods that increased output and reduced production costs but also to health and safety problems as well as exploration, land management, and reclamation. Equipment manufacturers and some Government agencies were constantly working on improving exploration, mining, and processing plant technology.

Significant technological developments instrumental in maintaining adequate production at relatively stable real costs were mostly in the processing plant technology. The use of computerized systems in plant operation and quality control increased; this, along with improved mining and processing equipment, permitted the recovery of salable fractions that were previously considered uneconomical.

Recycling.—Recycling of silica sands was limited to some foundry sands, particularly those used for making cores and molds with no-bake resin-bonded sands, some abrasive and airblasting sands, and, increasingly, post consumer glass and scrap glass that substitutes for glass sand. Most glass recycling was restricted to container glass, with green and amber being consumed at a higher rate than flint because it was more difficult to use in the batch mix. As the level of glass used increases, so does the level of quality required. Contamination of cullet by ceramics and nonmagnetic materials was an increasing concern. International trends toward increased recycling of glass and foundries sands and innovative ideas on recycling other materials should influence greater recycling of silica products.

Byproducts and Coproducts

Small amounts of gold and silver were recovered occasionally as a byproduct or coproduct from some unconsolidated silica sand deposits. Also, during the processing of some silica resources, other minerals, including clays, feldspars, mica, and quartz crystals, were produced as byproducts and coproducts.

Economic Factors

Silica sand deposits are nonrenewable resources. New mining methods combined with advances in mineral processing that were introduced during the past decade have increased the number of silica deposits that can be commercially developed.

The industrial sand industry was very competitive, largely because silica sand is a relatively abundant mineral, with supply usually exceeding demand. The delivered price of the product, in addition to quality, was a very important element in any major transaction. The producer with an operation closest to the market had a significant advantage over competitors. Combining sophisticated (and therefore expensive) processing equipment backed by technical knowledge and solid sales expertise was important. For this reason, only a small number of large companies were able to compete successfully and succeed in the silica sand business and supply a wide variety of products. Smaller, less efficient operations became uneconomical as operating costs, as well as costs associated with meeting various Federal, State, and local regulations, continued to increase. The only alternatives they had were to either limit the range of products they supplied to close markets or go out of business.

Prices.—As a result of rapidly rising costs of labor, energy, and mining and processing equipment, 1991 constant dollar prices of industrial sand rose steadily between 1973 to 1983. From 1985 to 1991, 1991 constant dollar prices fluctuated in the 15.25 to 16.25 range owing to decreased demand and tight competition in some markets. Prices should be expected to continue to fluctuate, although they should slowly rise as a result of the cost of compliance with more stringent environmental, land use, and safety regulations.

Costs.—Production costs for silica sand were determined to a large extent by the cost of labor, equipment, energy supply, water availability, and the additional burden of compliance with environmental and safety regulations. Production costs varied widely depending on the nature of the geologic deposit, the geographic location, and the type and number of products produced. Profits were relatively small for most producers, total production costs being close to the f.o.b. selling price per ton.

Tariffs.—There has been no tariff on imported silica sand containing 95% or more SiO_2 and not more than 0.6% iron oxide from most favored nations since January 1, 1987. For all other countries, the tariff for imported silica sand remains $1.94 per long ton.

Depletion Provisions.—The depletion allowance for industrial sand and gravel was 14%.

Operating Factors

Environmental Requirements.—Major environmental considerations that had to be dealt with in mining and processing of industrial sand and gravel were emission of particulate matter into the air, discharge of processing water, and noise abatement. Air pollution constituted a major problem in the processing plants, especially in the drying and packaging stages of finer products such as silica flour, silicosis being the major disease that can be contracted as a result of long-term exposure to silica dust. Because of the high cost of compliance with the environmental regulations designed to reduce this health hazard and possible long-term liabilities associated with it, some companies were no longer producing silica flour or did not plan to produce it in the future. Both wet and dry methods of dust control were used. The most important water pollutant was clay in suspension as a result of washing and screening silica sand. Because of the large quantities of water used to process silica sands and the need of compliance with stringent regulations, the treatment of discharge water by the sand producer was expected to require increasingly sophisticated and expensive processing methods. Significant progress was made in reducing noise pollution, both inside and outside of the operations, including noise and vibration produced by blasting and movement of heavy trucks.

Sand producers had to obtain mining permits from the appropriate governmental agency, which sometimes also required an Environmental Impact Statement (EIS) and a reclamation plan that met its guidelines or regulations. More and more emphasis was being put by local communities on improving the overall appearance of the operating mines as well as on land reclamation after mining was completed. At the same time, industry and the communities had to recognize the time and costs required to protect the environment and the importance of agreeing on fair and realistic environmental standards. Many States, counties, and towns had zoning laws that regulated land use.

Most of the active silica sand quarries as well as the known deposits were on private land, which was either owned or leased on a long-term basis by the producers. These deposits contained high-quality silica sand and were in the best locations with respect to markets. Unlike the construction sand and gravel industry, the industrial sand industry was usually not significantly affected by increasing land values near populated areas.

Transportation.—Transportation costs for silica sand were often equal or considerably greater than the cost of the product at the processing plant. Because of the large variety and number of consumers of silica sand, long distance haulage was not uncommon. In 1991, the largest tonnage, 56% of all industrial sand, was shipped by truck because most users require a versatile and rapid delivery system. Substantial quantities, 40% of the total, were also shipped by rail, especially when large volumes were sent long distances. The remaining tonnage was shipped by barge or used at the mine.

ANNUAL REVIEW

Production

The Midwest (East and West North Central regions) continued to lead the Nation in production, with about 42% of the 25.6 million tons produced in the United States, followed by the South

The industrial sand industry was very competitive, largely because silica sand is a relatively abundant mineral, with supply usually exceeding demand. The delivered price of the product, in addition to quality, was a very important element in any market transaction. The producer with an operation closest to the market had a significant advantage over competitors. Continuing sophistication that demands improved processing equipment backed by technical knowledge and solid sales expertise was important. For this reason, only a small number of large companies were able to compete successfully and succeed in the silica sand business and supply a wide variety of products. Smaller, less efficient operations became uneconomical, as operating costs, as well as costs associated with meeting various Federal, State, and local regulations, continued to increase. The only alternative they had were to either limit the range of products they supplied to other markets or go out of business.

Prices.—As a result of rapidly rising costs of labor, energy, and mining and processing equipment, 1993 constant dollar values of industrial sand rose steadily between 1973 and 1983. From 1983 to 1993, 1993 constant dollar prices decreased at the 13.23 to 19.21 range owing to decreased demand and stiff competition in some markets. Prices should be expected to continue to increase, although they should slowly rise as a result of the cost of compliance with more stringent environmental, land use, and safety regulations.

Costs.—Production costs for silica sand were determined to a large extent by the cost of labor, equipment, energy supply, water availability, and the additional burden of compliance with environmental and safety regulations. Production costs varied widely depending on the nature of the geologic deposit, the processing location, and the type and number of products produced. Profits were relatively small for most producers. Rail production costs being close to the f.o.b. selling price per ton.

Tariffs.—There has been no tariff on imported silica sand containing 95% or more SiO_2 and not more than 0.6% iron oxide from most favored nation since January 1, 1987. For all other countries, the tariff on imported silica sand remains $1.04 per long ton.

Depletion Provision.—The depletion allowance for industrial sand and gravel was 14%.

Operating Factors

Environmental Requirements.—Major environmental considerations that had to be dealt with in mining and processing of industrial sand and gravel were emission of particulate matter into the air, discharge of processing water, and noise abatement. Air pollution constituted a major problem in the processing plants, especially in the drying and packaging stages of finer products such as silica flour, silicosis being the major disease that can be contracted as a result of long-term exposure to silica dust. Because of the high cost of compliance with the environmental regulations designed to reduce this health hazard and possible long-term liabilities associated with it, some companies were no longer producing silica flour or did not plan to produce it in the future. Both wet and dry methods of dust control were used. The most important water pollutant was clay in suspension as a result of washing and desliming silica sand. Because of the large quantities of water used to process silica sands and the need of compliance with wastewater regulations, the treatment of discharge water by the sand producer was expected to require increasingly sophisticated and expensive processing methods. Significant progress was made in reducing noise pollution, both inside and outside of the operations, including noise and vibration produced by blasting and movement of heavy trucks.

Land reclamation, tied to obtaining mining permits from the appropriate governmental agency, which sometimes also required an Environmental Impact Statement (EIS) and a reclamation plan that met all guidelines or regulations. More and more emphasis was being put by local communities on inspecting the overall appearance of the operating mines as well as on land reclamation after mining was completed. At the same time, industry and the communities had to recognize the time and costs required to protect the environment and the importance of operating on fair and realistic environmental standards. Many States, counties, and towns had zoning laws that regulated land use.

Most of the active silica sand quarries as well as the known domestic reserves are on private land, which was either owned or leased on a long-term basis by the producers. These deposits contained high-quality silica sand and were in the best locations with respect to markets. Unlike the construction sand and gravel industry, the industrial sand industry was generally not significantly affected by increasing land values near populated areas.

Transportation.—Transportation costs for silica sand were often equal to or considerably greater than the cost of the product at the processing plant. Because of the large variety and number of consumers of silica sand, long distance hauling required consideration. In 1993, the largest tonnage, 70% of all industrial sand, was shipped by truck because rapid door-to-door delivery is a versatile and rapid delivery system. Substantial quantities, 25% of the total, were also shipped by rail, especially when long distances were not involved. The remaining tonnage was shipped by barge or used at the mine.

ANNUAL REVIEW

Production

The Midwest, West and West North Central regions continued to lead the Nation in production, with about 42% of the 25.6 million tons produced in the United States, followed by the South

(South Atlantic, East and West South Central regions) with about 36% and the West (Pacific and Mountain regions) with 14%. *(See table 2 and figure 1.)*

Based on the 1990 census estimations on population, 1991 U.S. per capita industrial sand and gravel production was 0.10 ton. Per capita production by major geographic region was 0.18 ton in the Midwest, 0.11 ton in the South, 0.07 ton in the West, and 0.05 ton in the Northeast.

The five leading States in the production of industrial sand and gravel, in descending order of volume, were Illinois, California, Michigan, New Jersey, and Texas. Their combined production represented 45% of the national total. Significant changes within the five major producing States included Texas, where production decreased almost 16%, and California, where production decreased by more than 14%. Production decreased in almost every State except in a few instances where production rose by a small percentage. *(See tables 3, 4, and 5.)*

The U.S. Bureau of Mines canvassed 77 producers of industrial sand and gravel with 148 active operations. About 74% of the industrial sand and gravel was produced by 44 operations, each with an annual production of more than 200,000 tons. The 10 leading producers of industrial sand and gravel were, in descending order of tonnage, Unimin Corp., U.S. Silica Co., Fairmount Minerals Ltd., The Morie Co. Inc., Oglebay Norton Co., Badger Mining Corp., Simplot Industries Inc., Construction Aggregates Corp., Owens-Illinois Inc., and WHIBCO Inc. Their combined production, from 63 operations, represented 72% of the U.S. total.

Consolidation of silica companies continued in 1991 as Fairmount Minerals acquired some of Manley Brothers of Indiana's operations from Hepworth Minerals and Chemicals Ltd. of the United Kingdom. The remaining Manley Brothers operation, in Illinois, was taken over by the management, which planned to maintain the Manley Brothers of Indiana name. The Securities Exchange Commission (SEC) ruled that Fairmount Minerals would not be allowed to purchase the entire Manley operation. The SEC determined the planned takeover was anticompetitive because of the change in market share distribution. With this purchase, Fairmount Minerals strengthens its hold as the third largest producer of industrial sand and gravel in the United States. Fairmount takes over mines and mills in two locations in Michigan as well as some other Manley facilities.

Spruce Pine Sand and Gravel, Franklin County, AL, discontinued sales of industrial gravel owing to the closure of elemental phosphorus plants at Olin and Occidental Chemicals' plants in Tennessee. Other producers also saw halts or decreases in gravel sales for elemental phosphorus production.

Ideal Basic Industries Inc. sold its Hempstead County, AR, operation to Holnam, Inc., a subsidiary of Financiere Glaris Ltd.

Salt Lake Valley Sand and Gravel temporarily shut down its facility for the production of abrasive blast sand.

Feldspar Corp. sold its ultrahigh-purity silica plant at Sprue Pine, NC, to Unimin Corp. Unimin is now the sole U.S. producer of ultrahigh-purity silica (less than 30 parts per million total impurities).

Consumption and Uses

Sand and gravel production reported by producers to the U.S. Bureau of Mines was actually material used by the companies or sold to their customers. Stockpiled material was not reported until consumed or sold.

Of the 25.6 million tons of industrial sand and gravel sold or used, 44% was consumed as glassmaking sand and 22% as foundry sand. Other important uses were abrasive sand (7%) and frac sand (5%). Because some producers did not report a breakdown by end use, their total production as well as the estimated production for nonrespondents were included in "Other uses, unspecified," which represented about 4% of the U.S. total.

On the regional level, more than one-third of the glassmaking sand was produced in the South (40%), followed by the Midwest (30%) and the West (17%). Three-fourths of the foundry sand was produced in the Midwest (74%). About three-fourths of the hydraulic fracturing sand was produced in the Midwest (73%), and the majority of the abrasive sand was produced in the South (65%). *(See table 6 and figure 2.)*

Northeast.—Cumberland County, NJ, continued to be the largest source for the glass and foundry sand markets in the region. Unimin, U.S. Silica, Morie, and WHIBCO Inc., all of which operated plants in the county, were among the largest producers of sand for these markets. U.S. Silica's plant in Huntingdon County, PA, also produced significant amounts of sand for the glass market. Morie's plant in Cumberland County and New Jersey Pulverizing Co.'s plant in Ocean County, NJ, produced a major percentage of the abrasive blast sand in the region.

Midwest.—Unimin's plants in LaSalle and Ogle Counties, IL; LeSueur and Scott Counties, MN; and Columbia County, WI, were among the leaders in producing sand for the glass, foundry, and frac sand markets. Fairmount Minerals, with operations in Berrien and Van Buren Counties, MI; Geauga County, OH; and La Salle County, IL, was a major producer of sand for the blast, foundry, frac, and glass sand markets in the region. U.S. Silica's plant in La Salle County, IL, and Badger Mining's plant in Jackson County, WI, were large producers for the glass and frac sand markets, respectively. Construction Aggregates Corp. in Ottawa County, MI, and U.S. Silica in LaSalle County, IL, were major producers of foundry sand in the region. Nugent Sand Co. Inc., in Muskegon County, MI, Badger Mining in Green Lake County, WI, and Sargent Sand Co. in Wexford County, MI, were also large producers for the foundry industry.

South.—Unimin and U.S. Silica Co. were two of the largest producers of sand

(South Atlantic, East and West South Central regions) with about 36% and the West (Pacific and Mountain regions) with 14%. (See table 2 and figure 3.)

Based on the 1990 census estimations on population, 1994 U.S. per capita industrial sand and gravel production was 0.10 ton. Per capita production by major geographic region was 0.15 ton in the Midwest, 0.11 ton in the South, 0.07 ton in the West, and 0.05 ton in the Northeast.

The five leading States in the production of industrial sand and gravel, in descending order of volume, were Illinois, California, Michigan, New Jersey, and Texas. Their combined production represented 45% of the national total. Significant changes within the five major producing States included Texas, where production decreased almost 16%, and California, where production increased by more than 11%. Production decreased in almost every State except in a few instances where production rose by a small percentage. (See tables 3, 4, and 5.)

The U.S. Bureau of Mines canvassed 77 producers of industrial sand and gravel with 148 active operations. About 74% of the industrial sand and gravel was produced by 47 operations, each with an annual production of more than 200,000 tons. The 10 leading producers of industrial sand and gravel were, in descending order of tonnage: Unimin Corp.; U.S. Silica Co.; Fairmount Minerals Ltd.; The Morie Co. Inc.; Oglebay Norton Co.; Badger Mining Corp.; Simplot Industries Inc.; Construction Aggregates Corp.; Owens-Illinois Inc.; and WEDRON Inc. Their combined production, from 57 operations, represented 72% of the U.S. total.

Consolidation of silica companies continued in 1994 as Fairmount Minerals acquired some of Manley Brothers of Indiana's operations from Hepworth Minerals and Chemicals Ltd. of the United Kingdom. The remaining Manley Brothers operation, in Illinois, was taken over by the management, which planned to maintain the Manley Brothers of Indiana name. The Securities Exchange Commission (SEC) ruled that Fairmount Minerals would not be allowed to purchase the entire Manley operation. The SEC determined the planned takeover was anticompetitive because of the change in market share distribution. With this purchase, Fairmount Minerals strengthened its hold as the third largest producer of industrial sand and gravel in the United States. Fairmount Minerals owns plants and mills in two locations in Michigan as well as some other Manley facilities.

Aycock Pit's Sand and Gravel, Franklin County, AL, discontinued sales of industrial gravel owing to the closures of elemental phosphorus plants of Olin and Occidental Chemicals' plants in Tennessee. Other producers also saw little or decrease in gravel sales for elemental phosphorus production.

Ideal Basic Industries Inc. sold its Hempstead County, AR, operation to Unimin Inc., a subsidiary of Flemington Watts Ltd.

Salt Lake Valley Sand and Gravel temporarily shut down its facility for the production of abrasive blast sand.

Feldspar Corp. sold its ultrahigh-purity silica plant at Spruce Pine, NC, to Unimin Corp. Unimin is now the sole U.S. producer of ultrahigh-purity silica with less than 30 parts per million total impurities.

Consumption and Uses

Sand and gravel production reported by producers to the U.S. Bureau of Mines was actually material used by the companies or sold to their customers. Stockpiled material was not reported until consumed or sold.

Of the 26.9 million tons of industrial sand and gravel sold or used, 36% was consumed as glassmaking sand and 23% as foundry sand. Other important uses were hydraulic fracturing (5%) and fiberglass sand (5%). Because some producers did not report a breakdown by end use, their total production as well as the estimated production for nonrespondents was included in "Other uses, unspecified," which represented about 4% of the U.S. total.

On the regional levels, more than one-third of the glassmaking sand was produced in the South (46%), followed by the Midwest (30%) and the West (17%). Three-fourths of the foundry sand was produced in the Midwest (74%). About three-fourths of the hydraulic fracturing sand was produced in the Midwest (73%), and the majority of the abrasive sand was produced in the South (45%). (See table 6 and figure 5.)

Northeast.—Cumberland County, NJ, continued to be the largest source for the glass and foundry sand markets in the region. Unimin, U.S. Silica, Morie, and WEDRON Inc., all of which operated plants in the county, were among the largest producers of sand for these markets. U.S. Silica's plant in Huntingdon County, PA, also produced significant amounts of sand for the glass market. Morie's plant in Cumberland County and New Jersey Pulverizing Co.'s plant in Ocean County, NJ, produced a major percentage of the abrasive blast sand in the region.

Midwest.—Unimin's plants in LaSalle and Ogle Counties, IL, LeSueur and Scott Counties, MN, and Columbia County, WI, were among the leaders in producing sand for the glass, foundry, and fracture sand markets. Fairmount Minerals, with operations in Berrien and Van Buren Counties, MI, Geauga County, OH, and La Salle County, IL, was a major producer of sand for the glass, foundry, and glass wool markets in the region. U.S. Silica's plant in La Salle County, IL, and Badger Mining's plant in Jackson County, WI, were large producers for the glass and frac sand markets, respectively. Construction Aggregates Corp. in Ottawa County, MI, and U.S. Silica in LaSalle County, IL, were major producers of foundry sand in the region. Nugent Sand Co. Inc., in Muskegon County, MI, Badger Mining in Green Lake County, WI, and Sargent Sand Co. in Midland County, MI, were also large producers for the foundry industry.

South.—Unimin and U.S. Silica Co. were two of the largest producers of sand

for the glass and foundry markets. Unimin's major plants were in Frederick County, VA; Richmond County, NC; Pontotoc County, OK; and Izard County, AR. U.S. Silica's Bullock County, AL; Morgan County, WV; Johnston County, OK, and Limestone County, TX, operations were the major contributors for these markets. Morie's Tuscaloosa County, AL, and Marion County, GA, plants were large producers of blast, foundry, and glass sand. Huey Stockstill Inc., Pearl River County, MS, Mid-State Sand and Gravel Co., Baywood and Baggett Parishes, LA, Pioneer Concrete of Texas Inc., Colorado and Liberty Counties, TX, Oglebay Norton's Texas Mining Co., McCulloch County, TX, and Specialty Sand Co., Colorado, Harris, and Newton Counties, TX, were large producers of blasting sand. W.R. Bonsal and Co., Anson County, NC, produced a large percentage of the industrial gravel used in the production of silicon and ferrosilicon. Oglebay Norton's Texas Mining Co. and Vulcan Materials Co., both in McCulloch County, TX, were the largest producers of frac sand in the region.

West.—Corona Industrial Sand Co., Owens-Illinois, Simplot Industries, and Unimin were the four largest producers of glass sand in the region, with major operations in Riverside County, CA, Amador County, CA, Clark County, NV, and Contra Costa County, CA, respectively. Lane Mountain Silica, Stevens County, WA, and Lone Star Industries Inc., Monterey County, CA, were the major suppliers for the sand blasting industry in the region. Simplot Industries also supplied a large portion of the foundry sand consumed.

Transportation

Of the total industrial sand and gravel produced, 56% was transported by truck from the plant to the site of first sale or use, unchanged from that of 1990; 40% was transported by rail, also unchanged from that of 1990; 3% by waterway; and only 1% was not transported. Because most of the producers did not report shipping distances or cost per ton per mile, no transportation cost data were available. *(See table 7.)*

Prices

Compared with that of 1990, the average value, f.o.b. plant, of U.S. industrial sand and gravel decreased slightly to $15.25 per ton. Average unit values for industrial sand and industrial gravel were $15.39 and $12.18 per ton, respectively. Nationally, industrial sand used as fillers for rubber, paint, and putty, etc., had the highest value per ton ($69.77), followed by silica flour, ($36.50), silica sand used in ceramics ($36.28), fiberglass (ground) ($35.70), scouring cleansers ($29.84), and frac sand ($27.10).

Unit values for different uses of industrial sand and gravel generally changed little from 1990 to 1991 even though total tonnage sold and used changed substantially. Despite the decreased sales for most uses, some uses underwent an increase in average value. These included sand for flat and specialty glasses, ground sand for fiberglass, foundry, filtration, frac, and sand used in roofing granules and fillers.

The average value per ton of industrial sand and gravel was highest in the West ($17.68), followed by the Northeast ($15.55), the South ($15.51), and the Midwest ($14.15). Glass sand average value per ton varied markedly, from $17.27 in the West to $9.74 in the Midwest. Tighter supplies and higher production costs in the West increased the cost of sand and gravel in this region.

Foreign Trade

Exports.—Exports of industrial sand, compared with those of 1990, increased 42% to 1,637,000 tons, and the value increased 27% to $106.7 million. Of this, 73% went to Canada, 13% went to Mexico, 3% went to Japan, and the remainder went to numerous other countries throughout the world.

Imports.—Compared with those of 1990, imports for consumption of industrial sand increased 25% to 91,000 tons valued at $932,000. More than 98% of this was lower value silica from the Federal Republic of Germany. Small amounts of specially prepared silica sand from Australia, Belgium, Canada, France, Italy, Japan, Mexico, Sweden, Switzerland, and the United Kingdom sold for very high values per ton. *(See tables 8 and 9.)*

World Review

World production of industrial sand and gravel, based on information usually provided by foreign Governments, was estimated to be 121.7 million short tons, a decrease of 6% from that of 1990. The Netherlands was the leading producer, followed by, in descending order, the United States, Argentina, the Federal Republic of Germany, and Japan. Most countries in the world had some production and consumption of industrial sand and gravel because of its basic uses in glass and foundries. However, because of variation in descriptions and usage for silica sand and gravel, it was difficult to get reliable information. Beyond those countries listed, many other countries were believed to have had some type of silica production and consumption. *(See table 10.)*

Current Research

Advances continued through 1991 into research involving glasses, glass fibers, silicon carbide, silicon nitride, silica fabrics, and fiber optics.

Corning Inc. reported that global demand for optical fiber expanded by 30% during 1990. Corning continued R&D in fiber-optic components that split, combine, or vary the intensity of optical signals. Corning urged Congress to remove barriers to competition that are inhibiting deployment of optical fiber to schools, homes, and hospitals as well as business.[4]

A new development involving rare-earth fluoride glasses found that

for the glass and foundry markets. Unimin's major plants were in Frederick County, VA; Richmond County, NC; Pontotoc County, OK; and Izard County, AR. U.S. Silica's Pickens County, AL; Morgan County, WV; Johnston County, OK; and Limestone County, TX, operations were the major contributors for these markets. Morie's Tuscaloosa County, AL, and Marion County, GA, plants were large producers of blast, foundry, and glass sand. Gray Stanfield Inc., Pearl River County, MS; Mid-State Sand and Gravel Co., Beauregard and Rapides Parishes, LA; Pioneer Concrete of Texas Inc., Colorado and Liberty Counties, TX; Oglebay Norton's Texas Mining Co., McCulloch County, TX; and Specialty Sand Co., Colorado, Harris, and Newton Counties, TX, were large producers of blasting sand. W.R. Bonsal and Co., Anson County, NC, produced a large percentage of the industrial gravel used in the production of silicon and ferrosilicon. Oglebay Norton's Texas Mining Co. and Voca Materials Co., both in McCulloch County, TX, were the largest producers of frac sand in the region.

West.—Corona Industrial Sand Co., Owens-Illinois, Simplot Industries, and Unimin were the four largest producers of glass sand in the region, with major operations in Riverside County, CA; Amador County, CA; Clark County, NV; and Contra Costa County, CA, respectively. Lane Mountain Silica, Stevens County, WA, and Lone Star Industries Inc., Monterey County, CA, were the major suppliers for the sand blasting industry in the region. Simplot Industries also supplied a large portion of the foundry sand consumed.

Transportation

Of the total industrial sand and gravel produced, 56% was transported by truck from the plant to the site of first sale or use, unchanged from that of 1990; 41% was transported by rail, also unchanged from that of 1990; 2% by waterway; and only 1% was not transported. Because most of the producers did not report shipping distances or cost per ton per mile, no transportation cost data were available. (See table 7.)

Prices

Compared with that of 1990, the average value, f.o.b. plant, of U.S. industrial sand and gravel increased slightly to $15.25 per ton. Average unit values for industrial sand and industrial gravel were $15.39 and $12.38 per ton, respectively. Nationally, industrial sand used as fillers for rubber, paint, and putty, etc., had the highest value per ton ($60.77), followed by silica flour, ($36.30), silica sand used in ceramics ($36.28), fiberglass (ground) ($35.73), roofing granules ($29.84), and frac sand ($27.10).

Unit values for different uses of industrial sand and gravel generally changed little from 1990 to 1991 even though total tonnage sold and used changed substantially. Despite the decreased sales for most uses, most uses underwent an increase in average value. Those included sand for flat and specialty glasses, ground sand for fiberglass, foundry, filtration, frac, and sand used as roofing granules and fillers.

The average value per ton of industrial sand and gravel was highest in the West ($17.55), followed by the Northeast ($15.53), the South ($15.81), and the Midwest ($14.15). Glass sand average value per ton varied markedly, from $17.27 in the West to $9.74 in the Midwest. Tighter supplies and higher production costs in the West increased the cost of sand and gravel in the region.

Foreign Trade

Exports.—Exports of industrial sand, compared with those of 1990, increased 42% to 1,557,000 tons, and the value increased 27% to $109.7 million. Of this, 72% went to Canada, 11% went to Mexico, 3% went to Japan, and the remainder went to numerous other countries throughout the world.

Imports.—Compared with those of 1990, imports for consumption of industrial sand increased 25% to 91,000 tons valued at $932,000. More than 58% of this was lower value silica from the Federal Republic of Germany. Small amounts of specially prepared silica sand from Australia, Belgium, Canada, France, Italy, Japan, Mexico, Sweden, Switzerland, and the United Kingdom sold for very high values per ton. (See tables 8 and 9.)

World Review

World production of industrial sand and gravel, based on information usually provided by foreign Governments, was estimated to be 121.7 million short tons, a decrease of 6% from that of 1990. The Netherlands was the leading producer, followed by, in descending order, the United States, Argentina, the Federal Republic of Germany, and Japan. Most countries in the world had some production and consumption of industrial sand and gravel because of its utility in glass and foundries. However, because of variations in descriptions and usage for silica sand and gravel, it was difficult to get reliable information. Beyond those countries listed, many other countries were believed to have various types of silica production and consumption. (See table 10.)

Current Research

Advances continued through 1991 in research involving plastics, glass fibers, silicon carbide, silicon nitride, silica fibers, and fiber optics.

Corning Inc. reported that global demand for optical fiber expanded by 30% during 1991. Corning continued R&D in fiber-optic components for use in vehicles, for very fast transfer of control signals. Corning urged Congress to remove barriers to competition that are inhibiting deployment of optical fiber to schools, homes, and hospitals as well as business.[7]

A new development involving rare-earth fluoride glasses known. The

lanthanide-doped fluoride fibers have a unique guiding configuration that allows the materials to be used as optical amplifiers and fiber lasers.[5]

Researchers reported a breakthrough in optical signal amplification that could slash the cost of future fiber-optic systems. The new amplifiers use special fluoride glass fibers treated with rare-earth praseodymium and boosted signal strength more than 1,000 times.[6]

A leaching process reportedly converts knitted and woven glass fabrics to silica, increasing the fabrics maximum operating temperature. The temperature-resistant fabrics are used for high-temperature insulation, welding protection, and metal filtration.[7]

Toyota Motors continues research into lightweighting to improve mileage and reduce air and noise pollution. Steel was replaced in seats by fiberglass springs, which improved passenger comfort while cutting the weight of the vehicles.[8]

A particulate silicon carbide metal matrix composite was used in the manufacture of a bicycle frame. The tubing used in the frame has a specific strength and stiffness higher than any other metallic frame material.[9]

Kyocera of Japan announced a new ceramic engine parts pilot plant to be built in Vancouver, WA. A spokesman said that the company would focus on components made from sintered silicon nitride ceramic. The material, compared to alumina ceramics, was claimed to be much less susceptible to thermal shock and able to maintain its strength at higher temperatures.[10]

Chemists at the University of California at Berkeley have blended polymers and glass at near-molecular level. The result, they say, was a composite one-half the weight of glass, but far stronger and nearly indistinguishable in clarity and resistance to scratches and corrosion.[11]

The construction industry is taking its first tentative steps toward what may one day be the widespread use of recycled, crushed, mixed-color glass as an aggregate fill around subsoil culverts, pipes, and drains. Increased use of recycled glass in this manner would increase use of virgin silica sand.[12]

In health-related matters, 3M Corp. announced a new respirator, 8825, which is believed to be the first dust, mist, and metal fume respirator to meet the requirements of TM14 Part 9.1, FFP2 Solid and Liquid. 3M stressed function and comfort in the design of this respirator, which is said to offer protection that exceeds exposure limits in most countries.[13]

In a related area, the U.S. Bureau of Mines recently carried out two studies that evaluated workers' dust exposures in automated-pallet-loading processes. The first study involved a dust control system using a push-pull ventilation technique that reduced dust exposure 76%. The second study evaluated different commercial automated-pallet-loading systems. A review was published in Mining Engineering Magazine.[14]

OUTLOOK

Demand

The forecast range of total U.S. demand in the year 2000 was expected to be 28 to 39 million short tons for industrial sand and gravel. Probable demand was expected to be about 34 million tons, which corresponded with an average annual growth rate of 3.4%. All forecasts were based on previous performances for this commodity within various end uses and contingency factors considered relevant to the future of the commodity. *(See tables 11, 12, and 13.)*

Glass Sand

Since 1987, annual demand for glass sand had fluctuated between 11.1 and 12.3 million tons. Sand consumed for container glass has decreased since 1987 mainly because some glass containers were being replaced by aluminum cans and plastic containers and also because the amount of glass being recycled was increasing. Additionally, many manufacturers of container glass were using thinner walls in glass containers, and this process had cut down the amount of sand used. Also, a new thinner and lighter safety glass was used in automobiles, and its use was growing. As a result of these contingency factors, demand for glass sand was expected to grow slowly until the year 2000. Probable demand for glass sand for the year 2000 was forecast to be 13 million tons, with a range of 12 to 15 million tons. The probable forecast indicated an annual growth rate of 1.8%.

Foundry Sand

The probable forecast for foundry sand was expected to be 8.5 million tons, and the range was expected to be 7 to 10 million tons. The probable forecast indicated an average annual growth rate of 5.4%. The use of foundry sand was seen to be dependent mainly on automobile production. Recently, many foreign automakers have opened plants in the United States, and this should support growth in sales of foundry sand as a greater percentage of cars sold in the United States will also be made in this country.

Hydraulic Fracturing Sand

This end use declined greatly in 1991, sinking to less than 1.4 million tons. Although the amount of hydraulic fracturing sand used in each oil and gas well increased, drilling activity decreased. This occurred because of lower than hoped for prices for oil and gas attributed to the stabilization of world oil markets after the Gulf War. However, demand was expected to grow for this end use during the decade, partially due to increased exports of frac sand. Probable demand for hydraulic fracturing sand for the year 2000 was expected to be 2.3 million tons, with a range of 1.7 to 2.7 million tons. The probable forecast indicated an annual growth rate of 4%.

Adequacy of Supply

Domestic production was expected to continue to meet more than 99% of demand through the year 2000. Imports,

mostly from Australia and Canada, were expected to remain minor.

The United States was the second largest producer and consumer of silica sand among the market economy countries and was self-sufficient in this commodity. Most of it was produced in the eastern part of the United States, where the largest deposits and major markets are. A significant amount of silica sand was also produced in the West and Southwest, mostly in California and Texas.

Because the unit price of silica sand was relatively low, except for a few end uses that required a high degree of processing, the location of silica sand deposits in relation to the market was an important factor that may work for or against a sand producer. Consequently, a significant number of relatively small operations supplied local markets with a limited number of products.

The constant-dollar price of domestic silica sand had fluctuated since 1983 and was expected to continue fluctuating because of strong competition among producers for retention of dwindling markets.

Possible Supply-Demand Changes

Several factors could affect supply-demand relationships for silica sand. Further increases in the development of substitute materials for glass and cast metals could reduce demand for glass sand and foundry sand but would increase demand for silica flour, which is used as a filler in plastics, and for glass fibers, which are used in reinforced plastics. Also, increased efforts to reduce waste and increase recycling could hinder glass sand demand. However, with advances in high-technology materials, silica sand may see increased consumption for ceramics, fiber optics, and other silicon and glass compounds. Although developments could cause demand for silica sand to decrease, the total value of production could increase because of the increased unit value of the new specialized sands.

An increase in the price of oil on the international market would stimulate domestic drilling and extraction from new and old oil deposits. This would increase demand for domestic hydraulic fracturing sand.

Concern over the use of silica as an abrasive due to health concerns and the imposition of stricter legislative and regulatory measures concerning silica exposure could decrease demands in many silica markets. Silica sand for use in the abrasive blast industry was being attacked as a health hazard as marketers of competing materials, including garnet, slags, and olivine, pushed the use of their "safer" abrasive medium.

Development of more efficient mining and processing methods are expected to continue. This will enhance development of lower grade silica sand deposits closer to markets but not presently mined. Such developments are expected to increase silica sand reserves.

---

[1]American Foundrymen's Society. Molding Methods and Materials. 1st ed., 1962, Des Plaines, IL, 619 pp.

———. Mold & Core Test Handbook. 1st ed., 1978, Des Plaines, IL, 388 pp.

[2]American Society for Testing and Materials. Standard Classification of Silica Refractory Brick. C 416-70 in 1984 Annual Book of ASTM Standards: V. 15.01, Refractories, Manufactured Carbon and Graphite Products; Activated Carbon. Philadelphia, PA, 1984, p. 140.

———. Standard Methods for Chemical Analysis of Silica Refractories. C 575-70 in 1984 Annual Book of ASTM Standards: V. 15.01, Refractories, Manufactured Carbon and Graphite Products; Activated Carbon. Philadelphia, PA, 1984, pp. 246-253.

[3]American Petroleum Institute. Recommended Practices for Testing Sand Used in Hydraulic Fracturing Operations. 1983, 13 pp.

[4]Ceramic Industry (Solon, OH). Corning Forecast Strong Optical Fiber Market. V. 137, No. 1, July 1991, p. 16.

[5]———. Fluoride Glasses Hold Commercial Promise as Fibers. V. 137, No. 6, Nov. 1991, pp. 10-11.

[6]Keller, John J. Big Cost Savings for Fiber-Optic Systems Are Seen in New Way To Amplify Signals. Wall Street J. (New York). V. 217, No. 114, June 12, 1991.

[7]Materials Edge (London). Fothergill Doubles Silica Fabric Capacity. No. 27, Aug. 1991, p. 14.

[8]———. Toyota Rolls Out New Materials Concepts. No. 29, Oct. 1991, p. 4.

[9]———. MMC Bike Wins Mountain Title. No. 31, Dec. 1991, p. 12.

[10]———. Kyocera Kick-Starts Ceramic Engines. No. 22, Mar. 1991.

[11]Wall Street Journal. Odds and Ends. V. 218, No. 44, p. B1.

[12]Engineering News-Record (New York). Plumbing Code Boosts Use of Glass for Fill. V. 227, No. 22, Dec. 2, 1991, p. 17.

[13]Industrial Minerals Magazine (London). 3M Dust Respirator. No. 280, Jan. 1991, p. 64.

[14]Cecala, A. B., and A. Covelli. Automation To Control Silica Dust During the Pallet Loading Process. Mining Engineering (Littleton, CO). V. 43, No. 12, Dec. 1991, pp. 1440-1443.

OTHER SOURCES OF INFORMATION

Bureau of Mines Publications

Mineral Commodity Summaries, annual.
Mineral Industry Survey, annual.

Other Sources

Ceramics Industry Magazine.
Engineering and Mining Journal.
Glass International Magazine.
Industrial Minerals Magazine.
Pit & Quarry Magazine.
Rock Products Magazine.

TABLE 1
SALIENT U.S. INDUSTRIAL SAND AND GRAVEL STATISTICS[1]

(Thousand short tons and thousand dollars)

	1987	1988	1989	1990	1991
Sold or used:					
Sand:					
Quantity	27,380	27,207	27,819	26,956	24,541
Value	$357,660	$376,202	$395,807	$420,871	$377,578
Gravel:					
Quantity	631	1,272	1,385	1,450	1,059
Value	$6,424	$11,796	$14,388	$15,284	$12,899
Total industrial:[2]					
Quantity	28,010	28,480	29,205	28,406	25,600
Value	$364,100	$388,000	$410,200	$436,200	$390,477
Exports:					
Quantity	758	1,060	2,060	1,155	1,637
Value	$21,253	$30,843	$78,308	$83,826	$106,606
Imports for consumption:					
Quantity	104	43	35	73	91
Value	$1,071	$1,918	$2,057	$3,148	$932

[1]Puerto Rico excluded from all industrial sand and gravel statistics.
[2]Data may not add to totals shown because of independent rounding.

TABLE 2
INDUSTRIAL SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES BY GEOGRAPHIC REGION

Geographic region	1990				1991			
	Quantity (thousand short tons)	Percent of total	Value (thousands)	Percent of total	Quantity (thousand short tons)	Percent of total	Value (thousands)	Percent of total
Northeast:								
New England	154	1	$3,755	1	148	1	$4,107	1
Middle Atlantic	2,483	8	37,315	9	2,322	7	34,294	9
Midwest:								
East North Central	9,562	34	124,665	28	8,869	35	120,355	31
West North Central	1,948	7	31,688	7	1,679	7	28,867	7
South:								
South Atlantic	4,098	14	66,430	15	3,986	16	64,837	17
East South Central	1,533	5	17,761	4	1,261	5	15,921	4
West South Central	4,408	16	81,075	19	3,768	15	59,021	15
West:								
Mountain	1,477	5	19,803	5	1,220	5	16,828	4
Pacific	2,745	10	53,663	12	2,348	9	46,247	12
Total[1]	28,406	100	436,200	100	25,600	100	390,477	100

[1]Data may not add to totals shown because of independent rounding.

TABLE 3
INDUSTRIAL SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES, BY STATE

(Thousand short tons and thousand dollars)

State	1990 Quantity	1990 Value	1991 Quantity	1991 Value
Alabama	878	9,075	531	6,133
Arizona	W	W	W	W
Arkansas	742	7,209	746	7,738
California	2,452	48,055	2,104	41,690
Colorado	W	W	W	W
Connecticut	W	W	W	W
Florida	520	7,024	551	5,989
Georgia	W	W	W	W
Idaho	552	6,234	W	W
Illinois	4,486	62,531	4,146	57,210
Indiana	W	W	W	W
Kansas	W	W	W	W
Kentucky	W	W	W	W
Louisiana	559	10,003	W	W
Maryland	W	W	W	W
Massachusetts	30	401	30	401
Michigan	2,310	19,285	2,093	18,464
Minnesota	W	W	W	W
Mississippi	W	W	W	W
Missouri	W	W	W	W
Montana	W	W	W	W
Nebraska	W	W	W	W
Nevada	607	W	546	W
New Jersey	1,762	26,190	1,634	23,738
New York	W	W	W	W
North Carolina	1,177	15,338	1,174	15,565
Ohio	1,349	24,205	1,294	23,462
Oklahoma	1,258	22,984	1,241	20,918
Pennsylvania	W	W	W	W
Rhode Island	W	W	W	W
South Carolina	844	15,972	822	16,348
Tennessee	W	W	W	W
Texas	1,849	40,880	1,557	27,002
Utah	2	42	—	—
Virginia	W	W	W	W
Washington	W	W	W	W
West Virginia	W	W	W	W
Wisconsin	W	W	W	W
Other	7,027	120,728	7,132	125,820
Total[1]	28,406	436,200	25,600	390,477

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Data may not add to totals shown because of independent rounding.

TABLE 4
INDUSTRIAL SAND AND GRAVEL PRODUCTION IN THE UNITED STATES IN 1991, BY SIZE OF OPERATION

Size range (short tons)	Number of operations	Percent of total	Quantity (thousand short tons)	Percent of total
Less than 25,000	29	19.5	309	1.2
25,000 to 49,999	22	14.9	851	3.3
50,000 to 99,999	26	17.6	1,839	7.2
100,000 to 199,999	27	18.2	3,702	14.5
200,000 to 299,999	14	9.5	3,389	13.2
300,000 to 399,999	12	8.1	4,288	16.8
400,000 to 499,999	7	4.7	3,207	12.5
500,000 to 599,999	2	1.4	1,133	4.4
600,000 to 699,999	3	2.0	1,861	7.3
700,000 and over	6	4.1	5,021	19.6
Total	148	100.0	25,600	100.0

TABLE 5
NUMBER OF INDUSTRIAL SAND AND GRAVEL OPERATIONS AND PROCESSING PLANTS IN THE UNITED STATES IN 1991, BY GEOGRAPHIC REGION

Geographic region	Mining operations on land				Dredging operations	Total active operations
	Stationary	Portable	Stationary and portable	No plants or unspecified		
Northeast:						
New England	4	—	—	—	—	4
Middle Atlantic	8	—	2	1	5	16
Midwest:						
East North Central	31	1	2	—	2	36
West North Central	7	—	—	—	4	11
South:						
South Atlantic	15	—	—	3	7	25
East South Central	11	—	—	—	3	14
West South Central	9	—	—	2	11	22
West:						
Mountain	8	—	—	—	1	9
Pacific	10	—	—	1	—	11
Total	103	1	4	7	33	148

TABLE 6

INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 1991, BY MAJOR END USE

Major use	Northeast			Midwest			South			West			U.S. total[1]		
	Quantity (thousand short tons)	Value (thousands)	Value per ton	Quantity (thousand short tons)	Value (thousands)	Value per ton	Quantity (thousand short tons)	Value (thousands)	Value per ton	Quantity (thousand short tons)	Value (thousands)	Value per ton	Quantity (thousand short tons)	Value (thousands)	Value per ton
Sand:															
Glass-making:															
Containers	1,144	$16,485	$14.41	1,817	$14,849	$8.17	2,368	$30,175	$12.74	1,510	$26,482	$17.54	6,839	$87,992	$12.87
Flat (plate and window)	W	W	13.24	W	W	9.06	1,569	19,969	12.73	332	5,213	15.70	2,733	32,923	12.05
Specialty	W	W	17.10	411	6,050	14.72	W	W	17.04	23	627	27.26	775	12,497	16.13
Fiberglass (unground)	W	W	4.53	305	3,879	12.72	W	W	7.73	W	W	15.10	490	5,436	11.09
Fiberglass (ground)	—	—	—	W	W	38.20	W	W	35.76	W	W	21.75	314	11,210	35.70
Foundry:															
Molding and core	W	W	14.95	4,107	43,245	10.53	1,047	11,424	10.91	W	W	18.31	5,641	62,289	11.04
Molding and core facing (ground)	—	—	—	W	W	16.35	—	—	—	—	—	—	W	W	16.35
Refractory	W	W	12.83	86	1,113	12.94	W	W	29.09	W	W	24.17	104	1,520	14.62
Metallurgical:															
Silicon carbide	—	—	—	W	W	24.11	W	W	9.04	2	45	22.50	246	4,496	18.28
Flux for metal smelting	—	—	—	—	—	—	W	W	6.20	—	—	—	W	W	6.20
Abrasives:															
Blasting	195	4,102	21.04	317	6,869	21.67	1,012	17,841	17.63	182	4,843	26.61	1,706	33,655	19.73
Scouring cleansers (ground)	W	W	62.00	W	W	29.40	W	W	45.29	—	—	—	W	W	29.84
Chemicals (ground and unground)	W	W	23.67	W	W	10.02	W	W	18.66	49	921	18.80	561	9,215	16.43
Fillers (ground):															
Rubber, paints, putty, etc.	15	398	26.53	W	W	81.53	118	8,562	72.56	W	W	18.60	187	13,047	69.77
Silica flour	—	—	—	W	W	38.17	W	W	27.58	W	W	33.00	183	6,679	36.50
Ceramic (ground):															
Pottery, brick, tile, etc.	W	W	18.69	63	2,292	36.38	81	3,237	39.96	W	W	50.00	162	5,878	36.28
Filtration	102	1,754	17.20	63	1,962	31.14	159	2,722	17.12	104	3,174	30.52	428	9,612	22.46

See footnotes at end of table.

TABLE 6—Continued

INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 1991, BY MAJOR END USE

Major use	Northeast Quantity (thousand short tons)	Northeast Value (thousands)	Northeast Value per ton	Midwest Quantity (thousand short tons)	Midwest Value (thousands)	Midwest Value per ton	South Quantity (thousand short tons)	South Value (thousands)	South Value per ton	West Quantity (thousand short tons)	West Value (thousands)	West Value per ton	U.S. total[1] Quantity (thousand short tons)	U.S. total[1] Value (thousands)	U.S. total[1] Value per ton
Sand:—Continued															
Traction (engine)	W	W	$2.49	121	$1,227	$10.14	55	$636	$11.56	W	W	$14.78	285	$2,418	$8.48
Roofing granules and filllers	W	W	13.71	W	W	15.62	274	3,354	12.24	W	W	17.95	647	9,303	14.38
Hydraulic fracturing	—	—	—	1,012	28,962	28.62	W	W	22.55	W	W	25.57	1,355	36,718	27.10
Other uses, specified	934	$12,939	12.69	1,881	31,312	16.65	1,327	28,647	21.59	774	$14,660	18.94	XX	XX	XX
Other uses, unspecified[2]	69	2,463	35.70	198	4,837	24.43	479	6,533	13.64	234	3,775	16.13	981	17,608	17.95
Total[1] or average	2,458	38,141	15.52	10,384	146,594	14.12	8,489	133,102	15.68	3,210	59,740	18.61	24,541	377,578	15.39
Gravel:															
Metallurgical:															
Silicon, ferrosilicon	—	—	—	W	W	10.00	W	W	12.48	W	W	25.00	582	7,051	12.12
Filtration	12	260	21.67	W	W	50.00	W	W	14.80	—	—	—	63	1,191	18.90
Nonmetallurgical flux	—	—	—	—	—	—	—	—	—	W	W	9.22	W	W	9.22
Other uses, specified	—	—	—	164	2,627	16.02	526	6,678	12.70	357	3,334	9.34	415	4,656	11.22
Total[1] or average	12	260	21.67	164	2,627	16.02	526	6,678	12.70	357	3,334	9.34	1,059	12,899	12.18
Grand total[1] or average	2,469	38,401	15.55	10,548	149,221	14.15	9,015	139,780	15.51	3,567	63,075	17.68	25,600	390,477	15.25

W Withheld to avoid disclosing company proprietary data; included with "Other uses, specified"; also included in "U.S. total" by use. XX Not applicable.

[1]Data may not add to totals shown because of independent rounding.

[2]Mostly estimated total production plus other uses (small quantities) as reported by producers.

TABLE 7
TRANSPORTATION OF INDUSTRIAL SAND AND GRAVEL IN THE UNITED STATES IN 1991 TO SITE OF FIRST SALE OR USE

Method of shipment	Quantity (thousand short tons)	Percent of total
Truck	14,383	56
Rail	10,289	40
Waterway	652	3
Not transported	276	1
Total	25,600	100

TABLE 8

U.S. EXPORTS OF INDUSTRIAL SAND AND GRAVEL, BY COUNTRY

(Thousand short tons and thousand dollars)

Country	1990 Quantity	1990 F.a.s. value[1]	1991 Quantity	1991 F.a.s. value[1]
North America:				
Canada	806	16,565	1,199	13,515
Mexico	92	1,957	214	4,086
Panama	10	277	11	291
Other	2	305	18	681
Total[2]	910	19,105	1,443	18,571
South America:				
Argentina	1	188	4	425
Chile	10	705	4	236
Colombia	1	116	(3)	57
Ecuador	1	176	(3)	52
Peru	1	91	7	278
Venezuela	1	384	2	437
Other	(3)	37	21	419
Total[2]	14	1,697	39	1,904
Europe:				
Belgium	24	1,428	9	1,291
Finland	2	67	5	104
France	1	94	1	103
Germany, Federal Republic of	11	2,700	10	3,145
Italy	4	1,055	5	600
Netherlands	15	1,838	10	5,556
United Kingdom	40	872	6	999
Other	5	470	23	1,059
Total[2]	99	8,524	72	12,857
Asia:				
Indonesia	32	1,144	2	325
Japan	64	44,867	54	65,114
Korea, Republic of	5	1,872	10	2,520
Singapore	16	4,899	6	2,768
Taiwan	5	849	7	1,179
Other	4	445	1	366
Total[2]	125	54,076	80	72,273
Middle East and Africa:				
Ghana	1	31	(3)	12
Israel	2	84	(3)	121
Saudi Arabia	(3)	33	1	275
South Africa, Republic of	(3)	13	(3)	70
Other	(3)	83	(3)	38
Total[2]	3	244	1	517
Australia	(3)	165	2	445

See footnotes at end of table.

TABLE 8—Continued

U.S. EXPORTS OF INDUSTRIAL SAND AND GRAVEL, BY COUNTRY

(Thousand short tons and thousand dollars)

Country	1990 Quantity	1990 F.a.s. value[1]	1991 Quantity	1991 F.a.s. value[1]
Oceania	(3)	10	(3)	39
Grand total[2]	1,155	83,826	1,637	106,606

[1]Value of material at U.S. port of export; based on transaction price, including all charges incurred in placing material alongside ship.
[2]Data may not add to totals shown because of independent rounding.
[3]Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 9

U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL SAND, BY COUNTRY

(Thousand short tons and thousand dollars)

Country	1990 Quantity	1990 C.i.f. value[1]	1991 Quantity	1991 C.i.f. value[1]
Australia	70	2,522	(2)	161
Canada	3	77	1	61
Germany, Federal Republic of	(2)	259	90	629
Japan	(2)	77	(2)	11
United Kingdom	(2)	62	(2)	21
Other	(2)	151	(2)	50
Total[3]	73	3,148	91	932

[1]Value of material at U.S. port of entry; based on purchase price and includes all charges (except U.S. import duties) in bringing material from foreign country to alongside carrier.

[2]Less than 1/2 unit.

[3]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 10
INDUSTRIAL (SILICA) SAND AND GRAVEL: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1987	1988	1989	1990	1991[e]
Argentina	9,974	10,645	9,434	[e]9,900	9,920
Australia	2,602	2,170	[e]2,210	[e]2,210	2,205
Austria	754	833	903	[r]902	905
Belgium	2,500	2,698	[e]2,900	[e]2,900	2,315
Brazil	[r]4,020	[r]4,520	[r]4,520	[r]4,100	4,080
Canada	2,934	3,094	2,904	[r]2,094	2,205
Chile[e]	330	330	330	330	330
Cuba[e]	[3]571	610	610	550	550
Denmark	[e]2	2	[e]2	[r]3	3
Ecuador	16	[e]55	113	[e]80	77
Egypt[4]	257	152	597	[e]550	550
Finland	257	300	311	[e]310	300
France[e]	[3]8,236	8,250	8,250	8,250	3,860
Germany, Federal Republic of:					
Western states	6,755	6,386	6,634	[r]6,756	7,410
Greece[e]	42	42	[r]67	[r]65	60
Guatemala	34	35	[e]34	[r] [e]33	33
Hungary	696	714	[r]715	[r]599	570
Iceland[e]	[3]5	5	5	5	5
India	4,173	3,239	2,782	[e]2,860	2,980
Indonesia	967	464	333	182	180
Iran[5]	667	914	907	761	880
Ireland	6	7	[e]8	[e]8	8
Israel	[e]66	66	72	93	94
Italy[e]	4,740	4,740	4,960	4,740	4,630
Jamaica	22	14	17	18	18
Japan	4,291	4,630	4,826	4,884	4,775
Kenya	([e] [6])	([e] [6])	12	[r]12	14
Korea, Republic of	1	2	1	[e]2	2
Malaysia	397	462	498	757	735
Mexico	1,094	1,104	1,341	1,431	1,310
Namibia[e]	8	7	7	7	7
Netherlands	24,553	28,659	28,271	27,709	27,560
New Zealand	[e]55	61	113	[e]110	45
Norway[e]	880	880	880	880	880
Pakistan	164	148	200	[e]190	145
Paraguay	2,087	2,123	2,137	[e]2,100	2,200
Peru	[r]84	[r]174	[r]83	[r]110	110
Philippines	185	281	342	[r]322	330
Portugal[e]	6	6	6	6	6
South Africa, Republic of	2,135	2,216	2,405	[r]2,189	[3]2,280
Spain	1,707	2,668	[e]2,205	[e]2,400	2,205
Sweden[e]	770	770	770	770	770
Tanzania	7	13	14	[r]7	8
Thailand	169	267	326	465	[3]725
Turkey	438	483	[r]546	[e]600	610

See footnotes at end of table.

TABLE 10—Continued

INDUSTRIAL (SILICA) SAND AND GRAVEL: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	1987	1988	1989	1990	1991[e]
United Kingdom	[r]4,441	4,784	4,828	[r]4,555	4,410
United States (sold or used by producers)	28,010	28,480	29,205	28,406	[3]25,600
Venezuela	502	502	417	[r]488	440
Yugoslavia	2,379	2,231	[r]3,465	[r]2,698	2,315
Zimbabwe	45	61	68	[r]69	69
Total	[r]125,034	[r]131,296	[r]132,584	[r]129,468	121,715

[e]Estimated. [r]Revised.

[1]Table includes data available through June 15, 1992.

[2]In addition to the countries listed, Angola, Antigua and Barbuda, the Bahamas, China, Israel, New Caledonia, Panama, and the U.S.S.R., among others, produce industrial sand, but current, available information is not adequate to formulate estimates of production levels.

[3]Reported figure.

[4]Fiscal years beginning July 1 of that stated.

[5]Fiscal years beginning Mar. 21 of that stated.

[6]Less than 1/2 unit.

TABLE 11
TIME-PRICE RELATIONSHIP FOR SILICA SAND

Year	Average annual price, dollars per ton, f.o.b. quarry	
	Actual price	Based on constant 1991 dollars
1971	3.49	11.04
1972	3.81	11.49
1973	3.80	10.77
1974	4.83	12.59
1975	5.50	13.08
1976	5.70	12.75
1977	6.82	14.27
1978	7.65	14.84
1979	8.57	15.31
1980	9.98	16.29
1981	11.15	16.53
1982	12.03	16.80
1983	12.63	16.95
1984	12.92	16.61
1985	12.75	15.80
1986	13.16	15.89
1987	13.06	15.28
1988	13.83	15.57
1989	14.23	15.36
1990	15.61	16.18
1991	15.39	15.39

[1]The implicit price deflators for 1991 are based on "gross domestic product" and not "gross national product," which was used previously. In addition, the base year is 1987, and not 1982, which was used previously.

TABLE 12
PROJECTIONS AND FORECASTS FOR U.S. INDUSTRIAL SAND, BY END USE, IN THE YEAR 2000

(Million short tons)

End use	1991	Year 2000		
		Forecast range		Probable
		Low	High	
Glass sand	11.2	12.0	15.0	13.0
Foundry sand	5.7	7.0	10.0	8.5
Hydraulic fracturing sand	1.4	1.7	2.7	2.3
Other	7.3	8.0	11.0	10.0
Total	25.6	28.7	38.7	33.8

TABLE 13

TEN-YEAR STATISTICAL DATA FOR INDUSTRIAL SAND SOLD OR USED BY U.S. PRODUCERS, BY SELECTED END USES

(Thousand short tons)

End use	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Glass[1]	12,252	9,436	11,341	10,293	10,993	11,873	12,141	12,293	11,728	11,158
Foundry[2]	7,118	6,670	7,239	5,143	5,777	[3]6,932	7,610	[3]7,085	[3]6,333	[3]5,745
Silicon carbide	140	94	135	121	W	130	W	W	191	246
Flux for metal smelting	191	74	97	67	46	114	117	45	23	W
Abrasive[4]	2,208	1,950	2,030	1,681	1,947	[5]1,848	2,113	[5]2,287	[5]2,298	[5]1,706
Chemicals	335	271	425	378	317	513	655	817	651	561
Fillers	192	141	200	158	267	394	225	227	369	370
Ceramics	226	179	184	150	198	225	280	238	143	162
Filtration	299	102	217	345	494	433	407	310	367	428
Traction (engine)	450	195	246	292	177	465	305	311	314	285
Roofing granules and fillers	517	296	289	403	261	392	575	790	572	647
Hydraulic fracturing	1,481	990	2,057	2,102	1,130	1,396	1,299	1,531	1,839	1,355

W Withheld to avoid disclosing company proprietary data.

[1]Includes container, flat, specialty, and fiber (sand and ground sand).

[2]Includes molding and core, molding and core facings (ground), and refractory uses.

[3]Excludes molding and core facings (ground).

[4]Includes blasting, sawing and sanding (1982, 1984-86), and scouring cleansers (ground).

[5]Excludes scouring cleansers (ground).

FIGURE 1
PRODUCTION OF INDUSTRIAL SAND AND GRAVEL IN THE UNITED STATES IN 1991, BY GEOGRAPHIC REGION

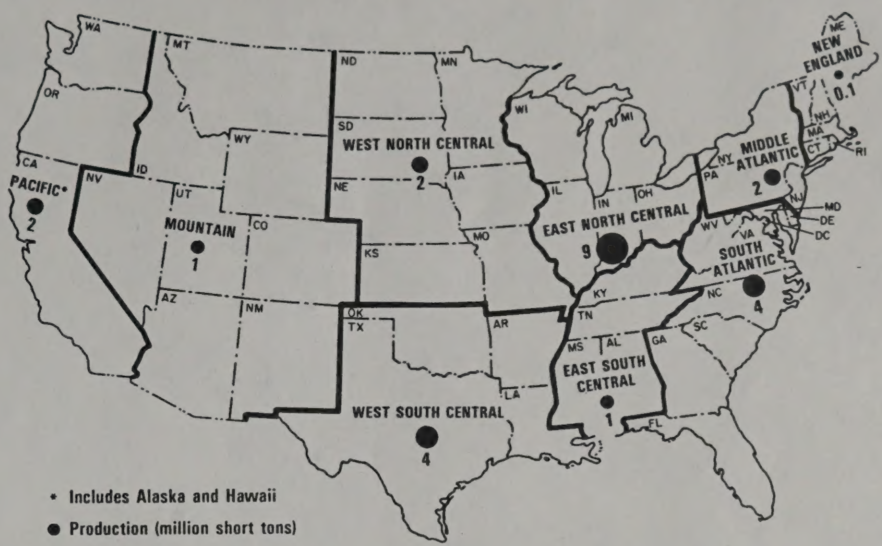
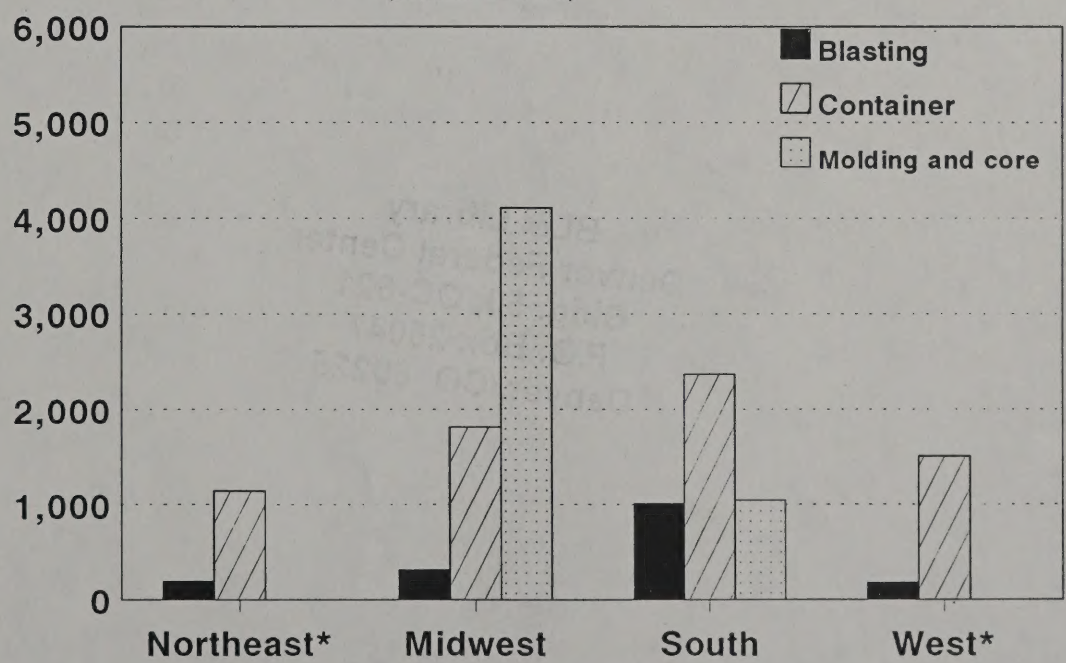


FIGURE 2
SAND USED IN SELECTED END USES, 1991
(Thousand short tons)



*Molding and core data withheld to avoid disclosing company proprietary data.